

# Effects of language experience, use, and cognitive functioning on bilingual word production and comprehension

**Kaitlyn A. Litcofsky**

Department of Psychology, Pennsylvania State University, USA

**Darren Tanner**

Department of Psychology, Pennsylvania State University, USA; Department of Linguistics, University of Illinois, USA

**Janet G. van Hell**

Department of Psychology, Pennsylvania State University, USA; Behavioural Science Institute, Radboud University Nijmegen, The Netherlands

## Abstract

**Aims and objectives/purpose/research questions:** Considerable research has investigated how bilinguals produce and comprehend words, focusing mainly on how bilinguals are able to select words from the appropriate language. Less research, however, has investigated whether production and comprehension involve the same underlying mechanisms. The present study explores this issue by examining whether production and comprehension, in the first language (L1) and second language (L2), are similarly influenced by factors relating to language experience, language use, and cognitive functioning.

**Design/methodology/approach:** Spanish-English bilinguals living in an English-speaking environment completed a picture naming task and a lexical decision task in their L1 and L2. In addition, participants completed the Operation Span task testing working memory and the Flanker task testing inhibitory control, and completed a language history questionnaire probing their language experience, relative proficiency, and codeswitching behavior.

**Data and analysis:** Performance on all tasks was submitted to correlation analyses and the impact of individual difference measures on word production and comprehension was assessed via regression analyses.

**Findings/conclusions:** Results showed that (1) production and comprehension were more closely linked in L1 than in L2; (2) production in L1 and L2 was predicted by language proficiency; and (3) comprehension in L1 and L2 was predicted by working memory.

---

## Corresponding author:

Kaitlyn A. Litcofsky, Department of Psychology, Pennsylvania State University, 006 Moore Building, University Park, PA 16802, USA.

Email: kaitlynlitcofsky@gmail.com

**Originality:** This is the first study to compare lexical processing in production and comprehension in both L1 and L2 and how these processes are influenced by language experience, use, and cognitive factors.

**Significance/implications:** Word production and comprehension appear to be more tightly linked in L1 than L2, but seem to rely on different processing mechanisms.

### **Keywords**

Production, comprehension, individual differences, lexical processing, bilingualism

## **Introduction**

A considerable amount of research has focused on how bilinguals select and produce words (for a review, see Kroll, Bobb, Misra, & Guo, 2008) and on how they comprehend words (for reviews, see Bultena & Dijkstra, 2012; Schwartz & Van Hell, 2012). However, less research has focused on the connection between these two processes, whether production and comprehension rely on the same or different cognitive mechanisms, and whether they are sensitive to the same or a different set of factors related to language experience and executive functions. Focusing on Spanish-English bilingual speakers, we compared word production and comprehension in the bilinguals' first (L1) and second (L2) language by examining the influence of factors relating to language experience, cognitive functioning, and language use on performance in these four domains.<sup>1</sup> Note that we use the term bilingual speakers to refer to any individual who knows and uses two languages, which includes simultaneous bilinguals, early and late sequential bilinguals, and heritage speakers (e.g., Rothman, 2009; for a recent review on heritage speakers, see Benmamoun, Montrul, & Polinsky, 2013). As will be discussed below, different views exist concerning the relationship between word production and comprehension that focus on whether the two processes rely on the same or different mechanisms. Given that word production and comprehension are often studied separately, this debate has not been thoroughly addressed. To the best of our knowledge, the current study is the first to systematically compare production and comprehension in L1 and L2 in the same group of bilingual speakers and to see how linguistic and cognitive individual difference factors affect L1 and L2 word production and comprehension.

### ***Word production***

Adult fluent speakers produce about two to three words per second in normal conversation. Models of word production (e.g., Caramazza, 1997; Dell, 1986; Levelt, Roelofs & Meyer, 1999; for a recent volume on word production, see Goldrick, Ferreira, & Miozzo, 2014) generally assume that when an individual intends to produce a specific word, or name a picture, speakers first activate a lexical concept, retrieve the appropriate word form (lemma), and then the morpho-phonological and articulatory codes. Accordingly, activation flows from the concept to its associated lemma, and finally to phonological and articulatory information. This activation is assumed to spread not only to the target word and its associated information, but also to related items and their information at each level of processing. Moreover, in bilingual word production, activation can spread to words in either the target or non-target language, necessitating some mechanism for selecting candidate words from only one language. There is debate concerning the locus of this restriction, whether it occurs earlier or later in the speech

production process (e.g., Costa, La Heij, & Navarrete, 2006; Kroll et al., 2008), and the mechanism underlying this restriction (e.g., general cognitive control mechanisms or an unspecified language mechanism). Recent studies also suggest that a bilingual's production system is a dynamic system that can operate in different cross-language activation states, depending on factors such as the bilingual's relative fluency in the L1 and L2 or cues in the linguistic or sentence context the target words or pictures are embedded in (e.g., Grosjean, 2001; Hermans, Ormel, Besselaar, & Van Hell, 2011).

In the study reported in this paper, word production in L1 and L2 will be investigated using the frequently used picture naming task. In this task, participants are presented with pictures and must first access the corresponding concept, then the associated lexical entry in the correct language, and finally verbalize the name, either in their L1 or in L2.

### *Word comprehension*

During word comprehension an individual is presented with a lexical form and must determine its meaning (and the flow of activation is in the opposite direction as in word production). Models describing the comprehension of visually presented words (for an overview, see Adelman, 2012) generally state that readers first need to identify letter features, then the letters themselves and finally the meaning of the word. Most current models assume that a word's orthographic, phonological, and semantic codes are engaged during word comprehension (for a review of different models, see, e.g., Balota, Yap, & Cortese, 2006; see also Adelman, 2012).

Historically, a central question in bilingual word recognition has been whether comprehension is language selective, that is, that words from only one language become activated, or language non-selective, that is, that words from either language become activated in parallel. Research conducted in the past decades, using different task paradigms and a wide variety of bilinguals, has reached a general consensus in favor of the language non-selective view (for a review, see Van Hell & Tanner, 2012). If the bilinguals' two languages are always active, then how do they resolve potential cross-language competition to allow fluent performance? According to some models (e.g., BIA+, Dijkstra & Van Heuven, 2002), some form of language tags or nodes are invoked that tie all the words of a given language together. When a word of one language gets strongly activated, its corresponding language node becomes activated, which in turn inhibits all words from the other language. This process allows the word to be comprehended in the appropriate language, and in the case of language-ambiguous words, the meaning in the target language can be selected. An emergent body of evidence suggests that bilinguals can also use contextual cues to constrain the activation to the target language (for a review, see Schwartz & Van Hell, 2012). An additional issue for bilinguals is that they are often unbalanced – that is, more proficient in one of their languages. Given this, what are the factors that affect the speed and success of lexical access in comprehension in both of their languages? Are the same mechanisms at work in the bilinguals' L1 and L2, despite differences in proficiency?

In the study reported in this paper, word comprehension will be investigated using a lexical decision task (LDT) in L1 and in L2. In this task, words and pseudowords (letter strings created by changing one or two letters of a real word) are presented. Participants must decide whether each letter string is an existing word in the specified language. During this task, participants must process the letter string and check whether it has an entry in their mental lexicon associated with the target language. If it does, the participant responds "yes". If there is no entry (i.e., for pseudowords), participants must press "no". Research has shown that the LDT in L1 and L2 engages orthographic, phonological, and semantic information (e.g., Balota et al., 2006; Van Hell & De Groot, 1998).

### *Word production and word comprehension: two sides of the same coin?*

Both word production and word comprehension in one of a bilingual's languages involve lexical access and selection of the appropriate language, but are the mechanisms involved in these two processes the same? Word production and comprehension engage different task demands: in production, the speaker must first conceptualize and activate potential lexical items and then settle on one word to produce (lest they produce a speech error), whereas in comprehension, the participant's task is to match the presented stimulus to an existing entry in the mental lexicon. For bilinguals, although research has shown that a bilinguals' two languages are co-activated at some point in both comprehension and production, a key difference between these two processes is that the bilingual reader is processing externally presented information, whereas the bilingual speaker intentionally chooses the target language and potentially exerts a higher level of control on which representations become activated. Recently, MacDonald (2013) argued that comprehension and production are separable processes, yet highly linked. More specifically, she claims that comprehension processes have developed in order to accommodate language utterances, which are shaped by the needs of the producer. Implicit in this argument is that the mechanisms underlying production and comprehension are distinct and shaped by different demands. More strongly, Costa and Santesteban (2004) argued that the inherent differences in task demands necessitate separable mechanisms for production and comprehension, and these are different enough to caution against generalizing experimental results across these two types of processes. Moreover, these differences in task demands may imply that the control a speaker can exert on the activation state of the bilingual language system may be different from the control a reader can exert. This would imply that inter-individual variations in executive control, and possibly language proficiency, have a more profound impact on word production than on word comprehension.

In contrast, French and Jacquet (2004) claim that the underlying mechanisms are functionally the same in comprehension and production, in L1 and in L2. They assert that there is no need for language tags or other methods of restricting access to a given language. Rather, connectionist models (e.g., Li & Farkas, 2002) are able to acquire a bilingual lexicon wherein words from the two languages are separated based on word association statistics, without the need for explicit language tags. Similarly, Pickering and Garrod (2004, 2013) claim that similar mechanisms are at work in comprehension and production based on the fact that in dialogue, interlocutors align at all levels of processing. They claim that comprehension is in fact a product of covert production on the part of the comprehender.

One method of discerning whether production and comprehension rely on the same or different mechanisms, and whether there are dissociations between these mechanisms during L1 versus L2 processing, is to examine whether the same variables similarly influence the two processes. Here, we focus on variables related to language experience, cognitive factors, and language use in Spanish-English bilinguals.

### *Individual difference factors*

Language experience, and in particular age of acquisition (AoA), has been invoked as a critical factor in L2 development: increased AoA is generally associated with decreased L2 performance or different mechanisms underlying L2 performance (e.g., Perani et al., 1998). In general, increased proficiency in a language should improve word production and comprehension. For bilinguals, increased length of immersion in an L2-speaking environment will reciprocally be associated with a decrease in the amount of L1 exposure. A natural consequence of this should be higher L2 proficiency and a simultaneous decrease in L1 proficiency. Typically, AoA and length of immersion are

inversely related in adult bilinguals such that earlier ages of acquisition are associated with increased lengths of immersion in a L2 setting (see, e.g., Unsworth, 2013). Therefore, we expect that an earlier AoA and more time spent in a L2-speaking country should improve L2 production and comprehension, but impair L1 production and comprehension. These effects for language experience factors should hold whether production and comprehension are shared or not, because proficiency should independently affect both processes.

Cognitive factors, specifically inhibitory control, have been implicated in bilingual processing as a means to manage the two languages. Recently, research has suggested that bilinguals have enhanced executive function, as compared to monolinguals (e.g., Bialystok, Craik, Klein, & Viswanathan, 2004). This advantage has been taken to stem from the need for bilinguals to inhibit one language in favor of using the other (e.g., Kroll et al., 2008), specifically at the level of production. If the processes of production and comprehension are the same (e.g., according to French & Jacquet, 2004), then individual variation in executive function should impact both production and comprehension, in both languages. If, on the other hand, production and comprehension are different processes (e.g., according to Costa & Santesteban, 2004), and if it is indeed true that cognitive control is more implicated in production than in comprehension, then individual variation in cognitive factors should impact word production but not, or to a smaller extent, comprehension.

Another cognitive factor, working memory, has been found to have an impact on reading comprehension in L1: individuals with higher working memory capacity show better reading comprehension (e.g., Daneman & Carpenter, 1980; Daneman & Merickle, 1996; McCutchen, 1996). Indeed, children with worse working memory also have worse word recognition and comprehension (Swanson & Berninger, 1995). A recent meta-analysis by Linck, Osthus, Koeth, and Bunting (2014) on the influence of working memory on L2 processing and proficiency found similar relationships between working memory and L2 production and comprehension. However, their L2 outcomes consisted of not only word processing tasks, but also phonological, orthographic, sentence, and discourse-level processing. Moreover, they call for research directly comparing the influence of working memory on L2 production and comprehension, targeting the same level of processing. The current study addresses this gap by examining the role of working memory on lexical processing in comprehension and production in L1 and L2. If production and comprehension rely on similar processing mechanisms, in L1 and in L2 alike, working memory should influence both L1 and L2 comprehension and production. If production and comprehension are distinct processes, then working memory should affect comprehension in L1 and L2 and to a lesser extent or not at all production in either language, given that previous work has not established clear links between working memory and production, but has shown links with comprehension (Daneman & Carpenter, 1980; Linck et al., 2014).

Finally, how bilinguals use their languages might influence their production and comprehension performance. One measure of language use is simply how much of the time does someone use their L1 or L2: the more one uses their L2 necessarily decreases L1 use, shifting performance in the two languages (e.g., Gollan, Montoya, Cera, & Sandoval, 2008). Like for increased L2 language experience in terms of earlier AoA, increased L2 daily use should improve production and comprehension in L2, but impair production and comprehension in L1, regardless of whether production and comprehension are shared.

Another measure of language use is how frequently a bilingual codeswitches (switches between their two languages). Codeswitching generally reflects a high level of proficiency in both languages, and is used by some bilinguals as a discourse choice or as part of societal conventions (for a review, see, e.g., Gardner-Chloros, 2009). Recent research has suggested that the frequency of codeswitching may, in fact, relate to executive function, although the precise nature of the effect differs across studies. Firstly, codeswitching has been found to relate to inhibitory control. Prior

and Gollan (2011) found that bilinguals who codeswitch more frequently in their daily life performed better at task switching, which is supposed to rely on inhibitory control. Similarly, Yim and Bialystok (2012) found that those who codeswitched more frequently outperformed those who did not on a measure of verbal task switching, but not on non-verbal task switching. However, Soveri, Rodriguez-Fornells, and Laine (2011) examined the relationship between codeswitching and various executive functions and found no relationship between codeswitching and task switching (or inhibitory control). Instead, they found that a greater frequency of codeswitching predicted smaller mixing costs in a set shifting task (i.e., the performance of non-switch trials in a dual-task block minus the performance from a single-task block on a number-letter task in which participants had to decide either if the number was odd or even or if the letter was a vowel or consonant, depending on location of the presented number/letter string). Soveri et al. (2011) argue that mixing costs reflect sustained attentional monitoring of different task sets, an executive function similar to bilingual lexical selection wherein it is consistently necessary to monitor which language is appropriate given the situation. These findings suggest that language use, specifically frequency of codeswitching, is related to executive functions and should influence bilingual language processing. Both views of codeswitching, as relating to inhibitory control and to monitoring, suggest that the common mechanism lies in language selection in production. Therefore, like the predictions for inhibitory control above, a higher frequency of codeswitching should relate to better production in both languages. If production and comprehension rely on the same mechanisms, then this effect should extend to comprehension. If production and comprehension rely on distinct mechanisms, then codeswitching should have little or no impact on comprehension independent of its effect on production.

### *Current study*

The current study will compare performance on word production and comprehension in L1 and L2, and explore the influence of language experience factors (number of months spent in an L2-speaking environment and age of L2 acquisition), language use factors (percent current L2 use, codeswitching behavior), and cognitive factors (working memory and inhibitory control) on these processes. Spanish-English bilinguals completed a picture naming task and a Lexical Decision Task (LDT) in both their L1 and L2, two highly frequently used tasks in research on word production and word comprehension. Performance was evaluated through correlation and regression analyses to determine the relationship between L1 and L2 production and comprehension, as well as the influence of language experience, language use, and cognitive factors on L1 and L2 production and comprehension.

To summarize our predictions, if production and comprehension rely on the same mechanisms (e.g., French & Jacquet, 2004), then there should be positive correlations between production and comprehension performance both in the L1 and in the L2. If, however, they rely on distinct processes (e.g., Costa & Santesteban, 2004), then production and comprehension should not be correlated in either language. In addition, we examined how individual difference factors relate to production and comprehension in L1 and L2. The contrasting predictions discussed above are summarized in Table 1.

## **Methods**

### *Participants*

Forty-two Spanish-English bilinguals (mean age: 22.4 years; range 18–35; 29 female) participated in this experiment. Participants were recruited from the Pennsylvania State University undergraduate and

**Table 1.** Effect of individual difference factors on production and comprehension in first language (L1) and second language (L2).

	LI Prod	LI Comp	L2 Prod	L2 Comp
<i>If production and comprehension rely on similar mechanisms</i>				
Increased L2 experience	↓	↓	↑	↑
Cognitive factors				
<i>Inhibitory control</i>	*	*	*	*
<i>Working memory</i>	*	*	*	*
Language use				
<i>Increased L2 use</i>	↓	↓	↑	↑
<i>More codeswitching</i>	*	*	*	*
<i>If production and comprehension rely on different mechanisms</i>				
Increased L2 experience	↓	↓	↑	↑
Cognitive factors				
<i>Inhibitory control</i>	*	–	*	–
<i>Working memory</i>	–	*	–	*
Language use				
<i>Increased L2 use</i>	↓	↓	↑	↑
<i>More codeswitching</i>	*	–	*	–

Up and down arrows indicate that the individual difference factor is predicted to have an increased or decreased effect on the outcome, respectively. Stars (“\*”) indicate that the factor will have an impact on the outcome, without direction specified. Dashes (“–”) indicate that no effect is predicted.

graduate student populations via fliers and word-of-mouth and were compensated for their time. All were native speakers of Spanish and came from the continental US, Puerto Rico, or a variety of Spanish-speaking countries (Argentina, Colombia, Dominican Republic, Ecuador, Mexico, Peru, Spain, and Venezuela). Thirteen of these bilinguals (mean age: 20.2 years; range 18–22; 10 female) can be considered heritage speakers of Spanish: they grew up in an environment where English was the majority language but spoke Spanish at home (mean age English acquisition: 4; range: 0–6). These heritage speakers rated themselves more highly proficient in English (mean: 9.5 out of 10; range 8.5–10) than in Spanish (mean: 8.3 out of 10; range 5.5–10). The non-heritage speakers (29 bilinguals) grew up in a Spanish-speaking environment and began learning English either in the classroom or when they moved to an English-speaking country (mean age English acquisition: 10.4 years; range: 3–24). These speakers rated themselves more highly proficient in Spanish (mean: 9.2 out of 10; range 5.75–10) than in English (mean: 8.3 out of 10; range 5.5–10). We will see in the *Results* section below that, as is to be expected, the heritage and non-heritage speakers differed in age of English acquisition, time spent in L2 English environment, and proficiency in Spanish and English, but did not differ on measures of working memory, inhibitory control, percent L2 use, and codeswitching behavior. Participants reported using both English and Spanish in their daily lives at the time of testing, and all but three reported using more English than Spanish, as can be expected given the language of their current environment. All participants provided their informed consent prior to testing.

## Measures

**Boston Naming Test.** The Boston Naming Test (BNT; Kaplan, Goodglass, & Weintraub, 2001) is a standardized vocabulary test that presents 60 images that participants must name out loud. Images are black-and-white line drawings that are presented on a white background. Trials began with a

fixation cross presented for 750 ms, followed by a 1500 ms blank screen and then the image, which remained on the screen until the participant responded or for a maximum of 5000 ms, and finally a 600 ms blank interstimulus interval (ISI). An additional eight items were presented for practice, identically to the experimental trials, but randomly ordered for each participant. Experimental items were always presented in the same order (from easier to more difficult).

The entire task was audio recorded (where the participant is identified by subject number only) for later transcription of the response and determination of accuracy by a native speaker of the language. Answers were considered correct if they matched the assigned picture name, were more specific (e.g., “tennis racquet” for “racquet”), or were equivalent Spanish words in another dialect (e.g., accepting “chupon” for “chupete” [pacifier]).

Participants completed this task in both Spanish and English, with the order of languages counterbalanced with respect to their self-reported dominant language in order to avoid carryover effects that may be stronger in one language direction (e.g., from the dominant to the weaker language). That is, half of the participants performed the BNT first in their dominant and second in their weaker language, and half performed first in their weaker and second in their dominant language. Accuracy (percent out of 60) was used as the variable of interest.

*Lexical decision task.* The LDT presented letter strings to the participant, who had to decide if the string is a word in the target language or not. There were two versions of this task, one in English and one in Spanish. In each version, there were 50 language-specific words and 50 language-specific pseudowords, matched on length (number of letters) within-language (English: word  $M=5.64$  ( $SD=1.63$ ), pseudoword  $M=5.88$  ( $1.57$ ); Spanish: word  $M=5.90$  ( $SD=1.58$ ), pseudoword  $M=5.98$  ( $SD=1.32$ );  $t_s < 0.75$ ,  $p_s > .45$ ).

Words and pseudowords were also matched on length across languages (word:  $t(98)=0.811$ ,  $p=.42$ ; pseudoword:  $t(98)=0.345$ ,  $p=.731$ ), and words were matched on log lemma frequency across languages ( $t(98)=0.226$ ,  $p=.822$ ). Frequency counts for English words were based on the log lemma frequencies from the CELEX lexical database (<http://celex.mpi.nl>; Baayen, Piepenbrock, & Van Rijn, 1993). Because the available frequency corpora in English and Spanish have different sizes, the frequency counts for the Spanish words were based on the log lemma frequency of their English translations in the CELEX database. Note these frequency counts for the Spanish words correlate significantly with frequency counts from a Spanish database, the Alameda corpus (Alameda & Cuetos, 1995):  $r=.629$ ,  $p < .001$ .

The letter strings were presented in the center of the screen in black type (Courier New, size 18) on a white background. Participants pressed one button to indicate if the letter string is a word in the given language and another button to indicate it is not a word.

Trials began with a fixation cross presented in the center of the screen for 500 ms, followed by a blank screen for 250 ms, and then the letter string, which was presented until the participant responded or for a maximum of 5000 ms. There were two list orders, each of which contained two blocks of items. Each block contained 50 items, half of which were real words, and half of which were pseudowords. Within each block, items were randomly ordered for each participant. There were an additional 12 practice items, six words and six pseudowords, which were presented identically to the experimental trials.

D-prime ( $d'$ ) scores were calculated for each participant by subtracting the standardized probability of the false alarm rate (i.e., responding “yes” to a pseudoword) from that of the hit rate (i.e., responding “yes” to a word). D-prime scores provide an unbiased measure of discrimination ability.

Like for the BNT, participants completed this task in both Spanish and English, with the order of languages counterbalanced with respect to their self-reported dominant language.

*Operation Span.* In this task of verbal working memory (Turner & Engle, 1989), participants were asked to judge whether a simple arithmetic problem was correct or not and, at the same time, retain between two and six words in memory that were presented interleaved between the math problems. The set size of words to remember increases throughout the task. From this task, we calculated the Operation Span (Ospan) score, which is a measure of the number of words a participant recalled correctly, provided that they also answered the math problem correctly. The maximum Ospan score is 60; higher scores reflect better working memory. Participants completed this task in their self-reported dominant language.

*Flanker.* The Flanker task (Eriksen & Eriksen, 1974; see also Emmorey, Luk, Pyers, & Bialystok, 2008) presents a red arrow pointing either leftward or rightward. This arrow can be “flanked” by various shapes, which can be either congruent or incongruent; across two blocks, 36 congruent and 36 incongruent test critical trials are presented, in addition to two blocks of just the red arrow (each block: 12 left- and 12 right-facing trials), two blocks of Go/No-go trials (each block: 18 go and 18 no-go trials), and a mixed block (18 congruent, 18 incongruent, 18 go, and 18 no-go trials). The participants’ task was to press a button indicating the direction that the red arrow is pointing. From this task we calculated the Flanker Effect, which reflects the difference between the average reaction times (RTs) to the incongruent trials and congruent trials in a block consisting of only these trial types. A smaller Flanker Effect reflects better inhibitory control (ability to ignore competing, incongruent stimuli).

*Language history questionnaire.* The language history questionnaire (LHQ) collected self-ratings of proficiency in reading, writing, speaking, and comprehension (Likert scales ranging from 1 (low) to 10 (high)), as well as a detailed history of participants’ language exposure, use, and learning history. Means for self-rated proficiency in Spanish and English across the four measures were calculated. It additionally included the 12 questions from the Bilingual Switching Questionnaire (BSWQ; Rodriguez-Fornells, Kramer, Lorenzo-Seva, Festman, & Münte, 2012), which assesses an individual’s codeswitching tendencies: how often a bilingual switches into their L1 (L1S); how often a bilingual switches into their L2 (L2S); how often a bilingual switches in specific situations, with certain people, or about certain topics (ContextCS); and how often a bilingual switches unintentionally (UnintendedCS). Higher scores on the BSWQ represent increased frequency of codeswitching in the participant’s daily life. Variables of interest from the LHQ include language experience variables (age of L2 English acquisition, AoA; number of months spent in a L2 English-speaking environment, NumMonthsL2) and language use variables (percent of the time L2 English is used currently, PercentL2Use; and the four codeswitching variables discussed above, L1S, L2S, CS, US).

### *Experimental session*

The language of communication between experimenter and participant was English. However, for tasks performed in Spanish, the instructions on the computer screen were in Spanish. The order of tasks was Ospan, BNT in one language, LDT in one language (in the same language as BNT just before), Flanker task, BNT in other language, LDT in other language (in the same language as BNT just before; as explained above, the language of the BNT and LDT tasks was counterbalanced). Participants took about 1 hour to complete these tasks.

### *Data analysis*

Firstly, we performed a correlational analysis on all measures to examine the relationships between the measures. Specifically, we were interested in whether the production (BNT) and comprehension

(LDT) measures correlated in L1 and/or in L2, whether the cognitive factors of working memory (Ospan) and inhibitory control (Flanker) correlated, and how the factors of language experience and use (codeswitching behavior) relate to measures of language performance and cognitive factors.

Secondly, to examine the influence of cognitive factors, language experience, and codeswitching behavior on L1 and L2 production and comprehension, we conducted four multiple regression analyses. The four dependent variables were Spanish BNT accuracy, Spanish LDT accuracy, English BNT accuracy, and English LDT accuracy. The minimum alpha level for demonstrating significance in all statistical tests was 0.05.

## Results

### *Heritage versus non-heritage speakers*

As described in the *Participants* section above, our group of Spanish-English bilinguals consisted of heritage and non-heritage speakers. To examine whether these two groups differed qualitatively, we first compared them on all outcome measures using *t*-tests. As compared to non-heritage speakers, heritage speakers acquired their L2 earlier ( $t(40)=4.365, p<.001$ ), spent more months in an L2 environment ( $t(40)=7.165, p<.001$ ), performed better on the English BNT ( $t(40)=-2.306, p=-.026$ ), and performed worse on the Spanish BNT ( $t(40)=5.732, p<.001$ ) and Spanish LDT ( $t(40)=5.159, p<.001$ ), but no differences between the two groups were found on the English LDT ( $p>.6$ ). The heritage speakers' performance on the BNT and LDT is consistent with having higher proficiency in English production and lower proficiency in Spanish production and comprehension than non-heritage speakers, likely related to their growing up in an English-speaking environment. These findings confirm our classification of individuals as heritage or non-heritage speakers on the basis of participants' self-rated proficiency in English and Spanish and AoA of English and Spanish as assessed in the LHQ. However, the heritage and non-heritage speakers did not differ on cognitive or language use measures (working memory, inhibitory control, percent L2 use, or codeswitching behavior; all  $ps>.11$ ). Thus, it seems that the heritage and non-heritage speakers represent two clearly distinguishable bilingual groups in terms of subjective L1 and L2 proficiency ratings and objective performance on L1 and L2 word production and comprehension tasks, but their cognitive performance and current language use are not qualitatively different (Benmamoun et al., 2013). Given that the differences between the two groups were restricted to relative proficiency, we combined the data of the heritage and non-heritage speakers in the analyses of the production and comprehension data we will turn to now.

### *Correlations between linguistic and cognitive measures*

To explore the relationships among linguistic and cognitive measures (language production and comprehension, language experience, language use, and cognitive factors), we first performed a correlation analysis; see Table 2. L1 Spanish production (BNT) and comprehension (LDT) correlated with each other such that better L1 production was related to better L1 comprehension, although there was no such production/comprehension correlation in L2 English. The finding that production and comprehension correlate in L1, but not in L2, suggests that the similarity of cognitive and linguistic mechanisms underlying production and perception is higher in L1 than in L2.

However, L1 and L2 production (BNT) and L1 and L2 comprehension (LDT) correlated with different sets of factors. Production in L1 and L2 did not correlate with any of the cognitive measures, but did correlate with language experience factors (both L1 and L2 production with L2AoA and NumMonthsL2): better production in L1 was associated with a later age of L2 acquisition and

Table 2. Correlations between linguistic and cognitive measures.

	LI Prod	L2 Prod	LI Comp	L2 Comp	WM	Inhib	AoA	Num Months L2	Percent L2 Use	L1S	L2S	CS	US
LI Prod	1												
L2 Prod	-.151	1											
LI Comp	.785***	-.168	1										
L2 Comp	-.064	.208	-.019	1									
WM	.044	.101	.231	.445**	1								
Inhib	-.277	.098	-.318*	-.004	.192	1							
AoA	.451**	-.635***	.452**	-.094	.107	-.150	1						
Num MonthsL2	-.780***	.494***	-.691***	.030	-.050	.270	-.532***	1					
Percent L2Use	-.180	.057	-.233	-.138	-.216	.004	-.204	.282	1				
L1S	.215	-.108	.162	.003	.143	.103	.395**	-.265	-.314*	1			
L2S	-.162	.208	-.110	.021	.208	-.012	-.141	.309	.510***	-.091	1		
Context CS	-.096	.147	-.015	-.129	.059	-.172	.152	.184	.014	.383*	.364*	1	
Unintended CS	.031	-.270	.000	.192	.340*	.142	.323	-.045	.053	-.008	.147	.066	1

LI Prod: Spanish production (BNT); L2 Prod: English production (BNT); LI Comp: Spanish comprehension (LDT); L2 Comp: Spanish comprehension (LDT); WM: working memory (Ospar); Inhib: inhibitory control (Flanker); AoA: Age of L2 acquisition; NumMonthsL2: Number of months spent in an L2 English-speaking environment; PercentL2Use: Percent of current use that is in L2; L1S: how often a bilingual switches into the L1; L2S: how often a bilingual switches into the L2; ContextCS/CS: how often a bilingual switches in specific situations, with certain people, or about certain topics; UnintendedCS/US: how often a bilingual switches unintentionally. Correlation (*r* values) are reported. Significance: \*,  $p \leq .05$ ; \*\*,  $p \leq .01$ ; \*\*\*,  $p \leq .001$ . Degrees of freedom for all correlations are 42, except for correlations involving the codeswitching factors, which have 39 degrees of freedom.

BNT: Boston Naming Test; LDT: lexical decision task; Ospar: Operation Span; AoA: age of acquisition; L1: first language; L2: second language; CS: codeswitching.

**Table 3.** Significant predictors from the regression analyses.

Dependent variable	Significant predictor(s)
L1 production	Fewer months in L2 environment
L2 production	Earlier age of L2 acquisition
L1 comprehension	Better working memory Fewer months in L2 environment
L2 comprehension	Better working memory

Regression analyses were separately conducted on four dependent variables. Predictor variables: Operation Span, Flanker, age of acquisition, and number of months in a L2 environment.  
L1: first language; L2: second language.

fewer months in a L2 environment, while better production in L2 was associated with an earlier age of L2 acquisition, and more months spent in a L2 environment. In other words, individuals with more L2 experience were better in L2 production, but worse in L1 production. Neither L1 nor L2 production correlated with any of the cognitive factors.

Unlike for production, comprehension in both L1 and L2 did correlate with cognitive factors. L1 LDT correlated with inhibitory control such that better L1 comprehension was associated with better inhibitory control (smaller Flanker interference effect) and L2 LDT correlated with working memory such that better L2 comprehension was associated with better working memory.

Moreover, L1 comprehension correlated with language experience factors (L2AoA and NumMonthsL2) such that better L1 comprehension was associated with a later age of L2 acquisition and fewer months spent in an L2 environment. That is, individuals with more L2 experience performed worse in L1 comprehension.

Interestingly, the measures of cognitive functioning did not correlate with each other, indicating that these two tasks are tapping into separable cognitive processes (this is not an isolated effect, see, e.g., Poarch & Van Hell, 2013). However, as expected, the measures of language experience correlated with each other where an earlier age of L2 acquisition was associated with longer time spent in a L2 environment.

In contrast to our predictions, codeswitching behavior did not correlate with production or comprehension in L1 or in L2. For correlations between codeswitching and measures of language experience, language use, and cognitive functions, see Table 2.

Given that the measures of L1 and L2 production and comprehension variously correlated with some of the language experience and cognitive factors, we next performed a series of regression analyses aimed at examining which factors uniquely predict performance in each of the production and comprehension domains. Because factors of language use (PercentL2Use and the four codeswitching measures) did not correlate with L1 or L2 production or comprehension, we did not include these in the subsequent regression analyses.

### Regression analyses

Regression analyses were conducted to identify impacts of cognitive factors and language experience on four dependent variables: L1 and L2 production (BNT) and L1 and L2 comprehension (LDT; see Table 3). Regression analyses determine the amount of variation in the dependent variables explained by the linear summation of the predictor variables, determine which predictor variables are uniquely related to the dependent variable while holding all others constant, and provide estimates of the magnitude and direction of those relationships. A separate regression model

was conducted for each of the four dependent variables to individually explore the effects of the predictor variables (Ospan, Flanker, AoA, NumMonthsL2) on performance. Predictor variables were entered simultaneously.

*L1 production (Spanish BNT).* The linear summation of the four predictor variables explained a large proportion of the variance in L1 production ( $R^2=.615$ , Adjusted  $R^2=.564$ ,  $F(4, 37)=14.77$ ,  $p<.001$ ). One predictor variable was significantly related to L1 production: NumMonthsL2 ( $b=-.002$ ,  $\beta=-.733$ ,  $t(37)=5.92$ ,  $p<.001$ ); better L1 production was predicted by fewer months spent in an L2 environment after controlling for the effects of the other independent variables.

*L2 production (English BNT).* The linear summation of the four predictor variables explained a moderate but significant proportion of the variance in L2 production ( $R^2=.472$ , Adjusted  $R^2=.415$ ,  $F(4, 37)=8.28$ ,  $p<.001$ ). One predictor variable was significantly related to L2 production: AoA ( $b=-.015$ ,  $\beta=-.541$ ,  $t(37)=3.82$ ,  $p<.001$ ); better L2 production was predicted by an earlier AoA of L2 after controlling for the effects of the other independent variables.

*L1 comprehension (Spanish LDT).* The linear summation of the predictor variables significantly explained a moderate but significant proportion of the variance in L1 comprehension ( $R^2=.555$ , Adjusted  $R^2=.507$ ,  $F(4, 37)=11.54$ ,  $p<.001$ ). Two predictor variables were significantly related to L1 comprehension: Ospan ( $b=.015$ ,  $\beta=.229$ ,  $t(37)=2.02$ ,  $p=.05$ ) and NumMonthsL2 ( $b=-.005$ ,  $\beta=-.580$ ,  $t(37)=4.36$ ,  $p<.001$ ); better L1 comprehension was predicted by better working memory and fewer months spent in an L2 environment after controlling for the effects of the other independent variables.

*L2 comprehension (English LDT).* This total model was significant ( $R^2=.232$ , Adjusted  $R^2=.149$ ,  $F(4, 37)=2.80$ ,  $p=.04$ ). One predictor variable was significantly related to L2 comprehension: Ospan ( $b=.018$ ,  $\beta=.486$ ,  $t(37)=3.28$ ,  $p<.01$ ); better L2 comprehension was predicted by better working memory after controlling for the effects of the other independent variables.

## Discussion

This study sought to determine whether the mechanisms underlying word production (picture naming) and comprehension (lexical decision) are similar in bilingual speakers by examining whether these processes are similarly affected by factors of language experience, language use, and cognitive functioning. We found a significant relationship between production and comprehension in L1, but not in L2. Moreover, production in L1 and L2 was related to language experience (better L1 production with shorter lengths of residence in an L2 environment and better L2 production given earlier ages of L2 acquisition), and comprehension in both languages was related to better working memory. Better L1 comprehension was additionally predicted by shorter lengths of residence in an L2 environment. The finding that L1 word production and comprehension performance are significantly related and both are predicted by language experience suggests that the processing mechanisms involved in L1 word production and comprehension are functionally similar. However, for L2, the fact that word production and comprehension were not related, and that different sets of factors predicted word production and comprehension, suggests that the mechanisms supporting L2 word production and comprehension are different (e.g., Costa & Santesteban, 2004; MacDonald, 2013), and are possibly shaped by different demands throughout L2 development and use.

That the processes of word production and comprehension are more tightly associated in L1 than in L2 may reflect the fact that the majority of bilinguals learned their L2 English at or after the

age of 4 (i.e., were successive bilinguals). Models of successive bilingualism typically assume an established (but still developing) L1 to which the L2 is associated in various ways (for an overview of different models, see Bhatia & Ritchie, 2012; Kroll & De Groot, 2005; Paradis, Genesee, & Crago, 2010; Tokowicz, 2015). However, despite different perspectives on how L2 and L1 are linked, or whether L2 relies on the same neural structures as L1, the models agree that there is greater variation in L2 than in L1. This greater variation is evident in the current findings in that production and comprehension are more related in L1 than in L2, which may be due to some individuals processing L2 similarly to L1 (i.e., with linked production and comprehension), and some individuals processing L2 differently from L1.

To the best of our knowledge, there is a remarkably small literature on the relationship between production and comprehension in L2 processing focusing on lexical processing, especially in adults. However, the finding of more closely linked production and comprehension of words in the L1 than in the L2 is supported by, for example, research on L2 acquisition in children focusing on the development of morphosyntax. In terms of native language acquisition, Hendriks and Koster (2010) note that children's language development typically involves an asymmetry between comprehension and production abilities, wherein comprehension generally precedes production, although the reverse pattern has also been found for specific structures like reflexives and pronouns. An asymmetry between production and comprehension in L2 in bilingual children has also been observed. Ågren and Van de Weijer (2013) examined the production and comprehension of French subject-verb number agreement in monolingual French children, and bilingual children who were either exposed simultaneously to French and Swedish, or successively to Swedish then French. Children performed an elicited production task in which they told a story about a series of pictures as well as a comprehension task in which they had to choose the picture matching an auditorily presented sentence. In comprehension, the two types of bilingual groups performed similarly, and bilingual children aged 8–10 performed similarly to the monolingual group (although bilingual children aged 5–7 performed less accurately than the monolinguals). In contrast, the production performance of the two groups of bilingual children for plural, but not singular, verb forms was impaired relative to monolingual children (and successive bilinguals performed more poorly than simultaneous bilinguals). So, the bilingual children performed similarly to monolinguals in comprehension, but not production, suggesting that there is an asymmetry between production and comprehension during morphosyntactic development in which production lags behind comprehension (but see Unsworth, 2007, for a different perspective). This pattern is corroborated by Chondrogianni and Marini's (2012) study of L2 acquisition in children who also found good comprehension but impaired production. L2 learners of English were as sensitive as monolingual English children to omissions of tense and non-tense morphemes in an online word monitoring task, but showed impaired production of third person singular *-s* and past tense *-ed* morphemes in a picture-elicited production task compared to the monolingual children. A similar asymmetrical pattern is found in a specific type of bilinguals, namely heritage speakers. As discussed by Polinsky and Kagan (2007), in the heritage language, speakers generally show stronger comprehension across all linguistic levels, while showing difficulties in production, often for complex morphosyntax. In summary, the pattern emerging from the studies just discussed suggests that L2 production and comprehension abilities are not equivalent in bilingual children in terms of their development of morphosyntax, and the current study extends these findings that L2 production and comprehension are not tightly linked to lexical processing in adult bilingual speakers.

Finally, measures of language use (percent L2 use, codeswitching behavior) did not relate to production or comprehension in L1 or L2, indicating that performance does not depend on bilinguals' current pattern of language use.

In addition, we found that, whereas measures of language use (percent L2 use, codeswitching behavior) did not relate to word production or comprehension in L1 or L2, working memory influences comprehension but not production, and that this pattern holds for both L1 and L2. This supports previous findings of an influence of working memory in L1 (Daneman & Carpenter, 1980) and L2 (Linck et al., 2014) comprehension. However, in contrast to Linck et al.'s (2014) findings, we did not find an effect of working memory on L2 production. This discrepancy may stem from the fact that we examined single-word production and Linck et al.'s production measures included sentence- and discourse-level processing, which may impose additional working memory demands for planning across multiple words and phrases.

Overall, performance on the production and comprehension tasks showed that word production and comprehension rely on similar mechanisms in the L1, but are more distinct in the L2. A closer look at the role of individual difference factors showed that, for both languages, production is affected by proficiency while comprehension is influenced by working memory. These findings have potentially important implications for models of bilingual production and comprehension. Future research should further explore the relationship between production and comprehension in L1 and L2 at other levels of linguistic processing, such as syntactic processing, using a wider range of production and perception tasks, for bilinguals of different levels of L2 proficiency, and whether it varies for bilinguals of more typologically distinct languages.

### Acknowledgements

We would like to thank Maria Allyon, Brandon Beachum, Allyson Carmona, Kevin Donley, Paige Elinsky, Gabrielle Fridman, Alejandra Rodriguez, and Kaylee Roupas for help with stimuli creation, data collection, and coding.

### Funding

This research was supported by National Science Foundation Grants BCS-1349110 to Janet G. van Hell and Ping Li and OISE-0968369 to Janet G. van Hell, Judith Kroll, and Giuli Dussias, and a Pennsylvania State University Graduate Fellowship to Kaitlyn A. Litcofsky.

### Note

1. Throughout this paper, L1 is defined as the first acquired language [in our study Spanish] and L2 is the second acquired language [in our study English].

### References

- Adelman, J. S. (2012). *Visual word recognition (Volumes 1 and 2)*. Hove, UK: Psychology Press.
- Ågren, M., & Van de Weijer, J. (2013). Number problems in monolingual and bilingual French-speaking children: A production/comprehension divide. *Language, Interaction and Acquisition*, 4, 25–50.
- Alameda, J. R., & Cuetos, F. (1995). *Diccionario de frecuencias de las unidades lingüísticas del castellano*. Oviedo, Spain: Servicio de Publicaciones Universidad de Oviedo.
- Baayen, R. H., Piepenbrock, R., & Van Rijn, H. (1993). *The Celex Lexical Database (cd-rom)*. Philadelphia, PA: University of Pennsylvania Linguistic Data Consortium.
- Balota, D. A., Yap, M. J., & Cortese, M. J. (2006). Visual word recognition: A journey from features to meaning (a travel update). In M. Traxler, & M. A. Gernsbacher (Eds.), *Handbook of psycholinguistics* (pp. 285–375). Amsterdam, The Netherlands: Elsevier.
- Benmamoun, E., Montrul, S., & Polinsky, M. (2013). Heritage languages and their speakers: Opportunities and challenges for linguistics. *Theoretical Linguistics*, 39, 129–181.
- Bhatia, T. K., & Ritchie, W. C. (2012). *The handbook of bilingualism and multilingualism* (2nd edition). Malden, MA: Wiley Blackwell.

- Bialystok, E., Craik, F. I. M., Klein, R., & Viswanathan, M. (2004). Bilingualism, aging, and cognitive control: Evidence from the Simon task. *Psychology and Aging, 19*, 290–303.
- Bultena, S., & Dijkstra, T. (2012). Lexical access in bilingual visual word recognition. In C.A. Chappelle, M. Gullberg & J. Williams (Eds.), *The Encyclopedia of Applied Linguistics*. Wiley-Blackwell.
- Caramazza, A. (1997). How many levels of processing are there in lexical access? *Cognitive Neuropsychology, 14*, 177–208.
- Chondrogianni, V., & Marini, T. (2012). Production and processing asymmetries in the acquisition of tense morphology by sequential bilingual children. *Bilingualism: Language and Cognition, 15*, 5–21.
- Costa, A., La Heij, W., & Navarrete, E. (2006). The dynamics of bilingual lexical access. *Bilingualism: Language and Cognition, 9*, 137–151.
- Costa, A., & Santesteban, M. (2004). Bilingual word perception and production: Two sides of the same coin? *Trends in Cognitive Sciences, 8*, 253.
- Daneman, M., & Carpenter, P. A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behavior, 19*, 450–466.
- Daneman, M., & Merikle, P. M. (1996). Working memory and language comprehension: A meta-analysis. *Psychonomic Bulletin & Review, 3*, 422–433.
- Dell, G. S. (1986). A spreading-activation theory of retrieval in sentence production. *Psychological Bulletin, 93*, 283–321.
- Dijkstra, T., & Van Heuven, W. J. B. (2002). The architecture of the bilingual word recognition system: From identification to decision. *Bilingualism: Language and Cognition, 5*, 175–197.
- Emmorey, K., Luk, G., Pyers, J. E., & Bialystok, E. (2008). The source of enhanced cognitive control in bilinguals: Evidence from bimodal bilinguals. *Psychological Science, 19*, 1201–1206.
- Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception & Psychophysics, 16*, 143–149.
- French, R. M., & Jacquet, M. (2004). Understanding bilingual memory: Models and data. *Trends in Cognitive Sciences, 8*, 87–93.
- Gardner-Chloros, P. (2009). Sociolinguistic factors in code-switching. In B. E. Bullock, & A. J. Toribio (Eds.), *The Cambridge handbook of linguistic code-switching* (pp. 97–113). Cambridge University Press.
- Goldrick, M., Ferreira, V., & Miozzo, M. (2014). *The Oxford handbook of language production*. Oxford, UK: University Press.
- Gollan, T. H., Montoya, R. I., Cera, C., & Sandoval, T. C. (2008). More use almost always means a smaller frequency effect: Aging, bilingualism, and the weaker links hypothesis. *Journal of Memory and Language, 58*, 787–814.
- Grosjean, F. (2001). The bilingual's language modes. In J. Nicol (Ed.), *One mind, two languages: Bilingual language processing* (pp. 1–22). Oxford, UK: Blackwell.
- Hendriks, P., & Koster, C. (2010). Production/comprehension asymmetries in language acquisition. *Lingua, 120*, 1887–1897.
- Hermans, D., Ormel, E., Van Besselaar, R., & Van Hell, J. (2011). Lexical activation in bilinguals' speech production is dynamic: How language ambiguous words can affect cross-language activation. *Language and Cognitive Processes, 26*, 1687–1709.
- Kaplan, E., Goodlass, H., & Weintraub, S. (2001). *Boston naming test* (2nd edition). Philadelphia, PA: Lippincott Williams & Wilkins Publishers.
- Kroll, J. F., Bobb, S. C., Misra, M., & Guo, T. (2008). Language selection in bilingual speech: Evidence for inhibitory processes. *Acta Psychologica, 128*, 416–430.
- Kroll, J. F., & De Groot, A. M. B. (2005). *Handbook of bilingualism: Psycholinguistic approaches* (pp. 9–29). Oxford, UK: Oxford University Press.
- Levelt, W. J. M., Roelofs, A., & Meyer, A. S. (1999). A theory of lexical access in speech production. *Behavioral and Brain Sciences, 22*, 1–75.
- Li, P., & Farkas, I. (2002). A self-organizing connectionist model of bilingual processing. In R. H. J. Altarriba (Ed.), *Bilingual sentence processing* (pp. 59–85). North-Holland: Elsevier.
- Linck, J. A., Osthus, P., Koeth, J. T., & Bunting, M. F. (2014). Working memory and second language comprehension and production: A meta-analysis. *Psychonomic Bulletin & Review, 21*, 1–23.

- MacDonald, M. C. (2013). How language production shapes language form and comprehension. *Frontiers in Psychology, 4*, 1–16.
- McCutchen, D. (1996). A capacity theory of writing: Working memory in composition. *Educational Psychology Review, 8*, 299–325.
- Paradis, J., Genesee, F., & Crago, M. (2010). *Dual language development and disorders: A handbook on bilingualism and second language learning* (2nd edition). Baltimore, MD: Paul H. Brooks Publishing Company.
- Perani, D., Paulesu, E., Sebastián-Gallés, N., Dupoux, E., Dehaene, S., & Bettinardi, V. (1998). The bilingual brain: Proficiency and age of acquisition of the second language. *Brain, 121*, 1841–1852.
- Pickering, M. J., & Garrod, S. (2004). The interactive-alignment model: Developments and refinements. *Behavioral and Brain Sciences, 27*(2), 212–225.
- Pickering, M. J., & Garrod, S. (2013). An integrated theory of language production and comprehension. *Behavioral and Brain Sciences, 36*, 329–347.
- Poarch, G., & Van Hell, J. G. (2013, May). *The development of cross-linguistic interaction and cognitive control in early L2 learners, bilinguals, and multilinguals*. Poster presented at the International Workshop on Bilingualism and Cognitive Control, Krakow, Poland.
- Polinsky, M., & Kagan, O. (2007). Heritage languages: In the ‘wild’ and in the classroom. *Language and Linguistics Compass, 1*(5), 368–395.
- Prior, A., & Gollan, T. H. (2011). Good language-switchers are good task-switchers: Evidence from Spanish–English and Mandarin–English bilinguals. *Journal of the International Neuropsychological Society, 17*, 682–691.
- Rodriguez-Fornells, A., Kramer, U. M., Lorenzo-Seva, U., Festman, J., & Münte, T. F. (2012). Self-assessment of individual differences in language switching. *Frontiers in Psychology, 2*, 1–15.
- Rothman, J. (2009). Understanding the nature and outcomes of early bilingualism: Romance languages as heritage languages. *International Journal of Bilingualism, 13*, 155–163.
- Schwartz, A. I., & Van Hell, J. G. (2012). Bilingual visual word recognition in sentence context. In J. S. Adelman (Ed.), *Visual word recognition* (II, pp. 131–150). Hove, UK: Psychology Press.
- Soveri, A., Rodriguez-Fornells, A., & Laine, M. (2011). Is there a relationship between language switching and executive functions in bilingualism? Introducing a within-group analysis approach. *Frontiers in Psychology, 2*, 1–8.
- Swanson, H. L., & Berninger, V. (1995). The role of working memory in skilled and less skilled readers’ comprehension. *Intelligence, 21*, 83–108.
- Tokowicz, N. (2015). *Lexical processing and second language acquisition*. New York, NY, and London, UK: Routledge.
- Turner, M. L., & Engle, R. W. (1989). Is working memory capacity task dependent? *Journal of Memory and Language, 28*, 127–154.
- Unsworth, S. (2007). L1 and L2 acquisition between sentence and discourse: Comparing production and comprehension in child Dutch. *Lingua, 117*, 1930–1958.
- Unsworth, S. (2013). Assessing the role of current and cumulative exposure in simultaneous bilingual acquisition: The case of Dutch gender. *Bilingualism: Language and Cognition, 16*, 86–110.
- Van Hell, J. G., & De Groot, A. M. B. (1998). Disentangling context availability and concreteness in lexical decision and word translation. *The Quarterly Journal of Experimental Psychology, 49A*, 41–63.
- Van Hell, J. G., & Tanner, D. (2012). Second language proficiency and cross-language lexical activation. *Language Learning, 62*, 148–171.
- Yim, O., & Bialystok, E. (2012). Degree of conversational code-switching enhances verbal task switching in Cantonese–English bilinguals. *Bilingualism: Language and Cognition, 15*, 873–883.

## Author biographies

Kaitlyn A. Litcofsky is a PhD candidate in Psychology and Language Science at the The Pennsylvania State University. Her research broadly examines interaction in language processing, currently in the cases of interaction across languages in bilingual codeswitching and interaction of production and comprehension at the lexical and syntactic level.

Darren Tanner is an assistant professor in Linguistics at the University of Illinois at Urbana Champaign. His research interests lie in sentence processing and psycholinguistics, second language acquisition and bilingualism, and electrophysiological measures of language processing (ERPs). His work primarily investigates grammatical processing and sentence parsing in native and nonnative English speakers, as well as the development of grammatical processing systems in novice second language learners and cross-language interactions in bilingual sentence processing. For more information, see <http://darrentanner.wordpress.com/>

Janet G. van Hell is a professor of Psychology and Linguistics at The Pennsylvania State University. Her Bilingualism and Language Development (BiLD) Lab studies cognitive and neurocognitive processes related to second language learning and the use of two languages in children and adults, as well as language processing in school-aged children with typical or atypical language development. She combines neuropsychological, behavioral, and linguistic techniques to study language development and bilingual language processing. For more information, see <http://bild.la.psu.edu/>